FABRICATING A SIMPLE FAN SYSTEM FOR SMALL LOW SPEED WIND TUNNEL AND STUDYING THE PARAMETER FOR FREQUENCY ADJUSTMENT

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ABSTRACT

Wind tunnel fan frequently come without control box or instrument especially for axial fan that widely sell in the market. This may lead to unfavourable condition which the fan speed could not be remote. We may severally found the fan that could be control by some fix parameter option such as velocity and we only could use that certain speed for testing. The speed of motor also could not be increase. In this research, fabrication of fan system of small low speed wind tunnel that can control speed by varying the frequency was performed. The connection used three phase of Miniature Circuit Breaker, AC inverter and fan motor. AC inverter was installed for controlling the frequency of motor. This AC inverter could remote the frequency according to user mode and could increase the frequency of the motor. The legs and base for the fan were added for attachment to horizontal wind tunnel. An experiment of varying the frequency to get the pressure in the test section was done. Graph was plotted, which is pressure versus frequency. An analysis was done based on the graph. Starting that point, the velocity was calculated in order to plot graph of velocity versus frequency. The relationship of the parameters was established. From this experiment, user could know and adjust the frequency according to the pressure and velocity that they desired simply by rotating the knob of the AC inverter.

ABSTRAK

Terowong angin kebanyakannya tidak mempunyai kotak kawalan atau instrumen terutamanya kipas axial yang banyak dijual di pasaran. Ini akan mengundang situasi di mana halaju kipas tidak boleh dikawal. Kita mungkin kerap melihat kipas yang boleh dikawal parameternya dengan pilihan- pilihan halaju tertentu yang telah ditetapkan dan hanya boleh menggunakan pilihan halaju tersebut dalam experimen. Halaju motor kipas juga tidak boleh dinaikkan lagi. Dalam penyelidikan ini, sistem kipas untuk terowong angin yang kecil dan berhalaju rendah dicipta di mana halajunya boleh di kawal dengan mengubah parameter frekuensi. Sambungan sistem ini menggunakan Miniature Circuit Breaker (MCB), AC inverter dan motor kipas. AC inveter disambung untuk mengawal frekuensi motor. AC inverter ini dapat dikawal mengikut kehendak pengguna serta dapat menaikkan lagi frekuensi motor. Pada kipas tersebut, kaki-kaki dan tapak dibuat untuk menyambungkannya dengan terowong angin yang melintang. Experimen yang mengubah frekuensi untuk mengukur tekanan dalam seksyen ujian terowong angin dijalankan. Graf diplotkan iaitu graf tekanan melawan frekuensi. Analisis dibuat dengan merujuk kepada graf tersebut. Dengan maklumat tersebut, halaju dikira untuk memplot graf halaju melawan frekuensi. Hubungan antara parameter-parameter tersebut dibuat. Daripada experimen ini, pengguna dapat mengetahui dan dapat mengubah frekuensi mengikut tekanan dan halaju yang diinginkan hanya dengan memusing punat pada AC inverter.

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LIST OF SYMBOLS

λ	Power factor
$\Delta ptot$	Total pressure-loss
Pm	Power input from Motor
A1	Test section cross section area
U1	Test section flow speed
ηf	Fan efficiency factor
ηm	Motor efficiency factor
ρ	Density
f	Frequency
P	Pressure
Pd	Dynamic pressure
V	Velocity

LIST OF ABBREVIATIONS

AC	Alternating current
Cfm	Cubic feet per minute
RPM	Revolution per minute
MCB	Miniature circuit breaker
PH	Phase

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Wind tunnel is a tools use nowadays to study the air flow that pass through the object such as airplanes, cars, and building structures. It can measure the aerodynamic force; lift, drag, lateral forces, yaw, roll, and pitching moments of the object tested. If the aerodynamic force such as drag force and pressure can be measure, this will help the designer of automobile especially to find the way to reduce the power usage in moving the vehicles.

For automotive, there is new addition which the wind tunnel is equipped with moving belt like a roadway that closer to real situation. In viewing the airflow that could not be seen with naked eyes, there are many ways to visualize it; by smoke, tufts, evaporating suspension, oil, fog and sublimation.

There are many types of wind tunnel. They are low-speed wind tunnel, high-speed wind tunnel, supersonic wind tunnel, hypersonic wind tunnel, subsonic and transonic wind tunnel. In this research, the subsonic wind tunnel will be use due to its small size and low speed.

For this research, the specific part that will be study is the fan. Fan is an important component in wind tunnel operation. Its main function is to blow air into the tunnel for simulating the airflow force act on the object. There is also fan that attached at the back of wind tunnel as the sucker to suck the air out from the tunnel. Design of the fan is critical in determining the size of the blade, number of blade, the shape, the spacing, the angle and so forth to control the type of airflow and their velocity. The standalone fan is connected to AC power supply to rotate the blade. The fan has cover to prevent object or dust that could disturb the rotation and for safety precautions.

1.2 Problem Statements

This research is done to fabricate the simple fan system of subsonic wind tunnel that could vary the speed in frequency parameter. There are some common problems which lead to this research; the fan speed could not be controlled efficiently according to user requirement. It usually fix speed variable and only have certain fix speed option.

In addition, user usually could not estimate the velocity and pressure of airflow in test section by setting the input frequency from fan motor. This is because the wind speed in test section is different from wind speed in diffuser. The inverter also shows frequency parameters only. Therefore, this research attempts to solve these problems.

1.3 Research Objectives

1. To fabricate fan system of subsonic wind tunnel that variable speed can be controlled and remote.

2. To establish the relationship of parameter between frequency and pressure plus frequency and velocity of this wind tunnel.

1.4 Research Questions

1. How to fabricate fan system that the variable speed can be controlled?

2. What is the relationship of parameter between frequency and pressure plus frequency and velocity of this wind tunnel?

1.5 Scope of Research

This research is limited by the fan that only use for small low speed wind tunnel experiments that is for Manufacturing Engineering Faculty students that fits in classroom or laboratory. The fan is only for subsonic wind tunnel that is low in speed.

The relationship that establish also limited to the specification of the wind tunnel use in this experiment.

1.6 Significances of Research

Due to high cost of large size wind tunnel, this small, lower cost wind tunnel project can be used by Manufacturing Engineering Students to study about the air flow. It also gives significance to the other researcher to increase the frequency of fan. The relationship could be used for the user to set immediate pressure or velocity.

1.7 Expected Outcomes

The end of this research, the outcome that has been expected is the system of subsonic wind tunnel fan that the speed could be remote is fabricated. Besides, the relationships between parameter such as frequency, pressure and velocity will be established.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

This chapter touches on literature review of wind tunnel and fan. It is limited to small low speed wind tunnel which is subsonic. It covered the power and flow losses, material of fan blade, pitch angle of fan blade, importance of reducing turbulence flow, importance of enclosed fan, axial fan blade loads, pitot tube as pressure measurement instrument, and reading the pressure parameter, causes of mean velocity variation, methods for improving the flow, axial flow fans, vane axial fans, maximum flow speed in test section and component used for turbulence control.

2.2 Power and Flow Losses

“A quick, back-of-the-envelope calculation predicted top centerline velocities in the neighborhood of about 40 m/s, or close to 90 mph. Of course, this calculation was incredibly optimistic as the power losses due to honeycomb, screens, and contraction were completely neglected, and maximum experimental velocities were only about 15 m/s, or about 33.5 mph.” (Tatman N, 2008)

“The available pressure rise through the fan indicates the capability of the fan to recover the flow losses caused by both the presence of a model and model support mechanism, and the wind tunnel walls, screens, etc., in the flow stream when the test velocity is as indicated.” (Hoehne V. O., 1967)

Both journals said that the power or flow losses will happen in experimental due to existence of honeycomb, screens, wind tunnel wall, model and so forth. So velocity of experimental will be different from the one that calculated.

"By measuring the dynamic pressure in the test section, q1, for a variation of fan rpm the power factor, λ, of the wind-tunnel can be estimated. The power factor is a measure of the total pressure-loss of the wind-tunnel circuit and can be compared to the computed total pressure-loss. It is defined as follows,

$$\lambda = \frac{\Delta p_{tot}}{\eta_f q_1} = \frac{P_m \eta_m}{A_1 U_1 q_1}$$

where Δptot is the total pressure-loss of the wind-tunnel circuit, Pm is the power input from the motor, A1 is the test section cross section area, U1 is the test section flow speed and ηf , ηm are the fan and motor efficiency factors respectively" (Lindgren B. *et al*, 2002)

2.3 Material of Fan Blade

"A commercially available Hartzell MP96-6 cooling tower fan is used to pump the air through the tunnel. The fan blades are fabricated of fiberglass, which would facilitate blade chord modifications to improve undesirable test flow conditions if needed. The pitch angle of each blade is adjusted individually with tooling that is designed specially for this purpose." (Hoehne V.O., 1967)

"The fan itself has three cambered blades, also made from sheet metal, and the whole unit is rated for an output of 5700 cubic feet per minute (cfm)." (Tatman N., 2008)

From these two researches, they use different material for making fan blade. For research Heohne V.O, he use fibreglass while Tatman N. use sheet metal. The fibreglass will make the chord easily modified. But in this project, the existing fan only comes in plastic and metal.

2.4 Pitch Angle of Fan Blade

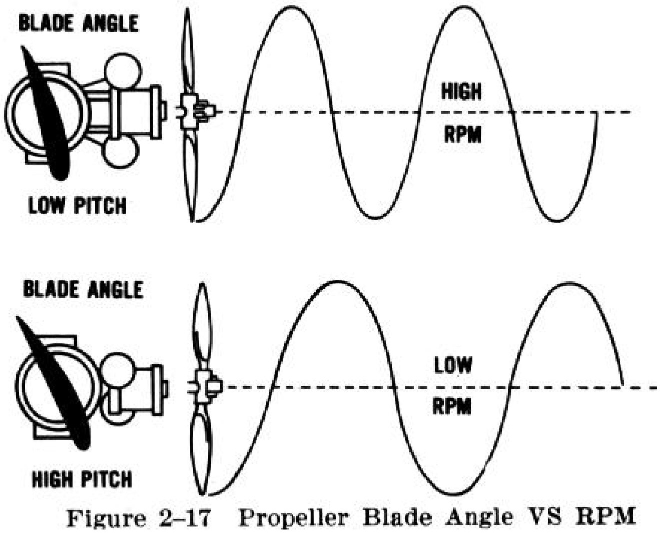

Figure 2.1: Fan Blade Angle versus RPM

A low pitch, high RPM setting, for example, can be utilized to obtain maximum power for takeoff; then after the airplane is airborne, a higher pitch and lower RPM setting can be used to provide adequate thrust for maintaining the proper airspeed. This may be compared to the use of low gear in an automobile to accelerate until high speed is attained, then shifting into high gear for the cruising speed. [1]

From this statement, it could be understand that controllable and adjustable pitch of blade could save power. This is because for starting-up, low pitch could be use because it is less friction and drag. When the high speed is reached, the high pitch will be use to maintain the speed of fan.

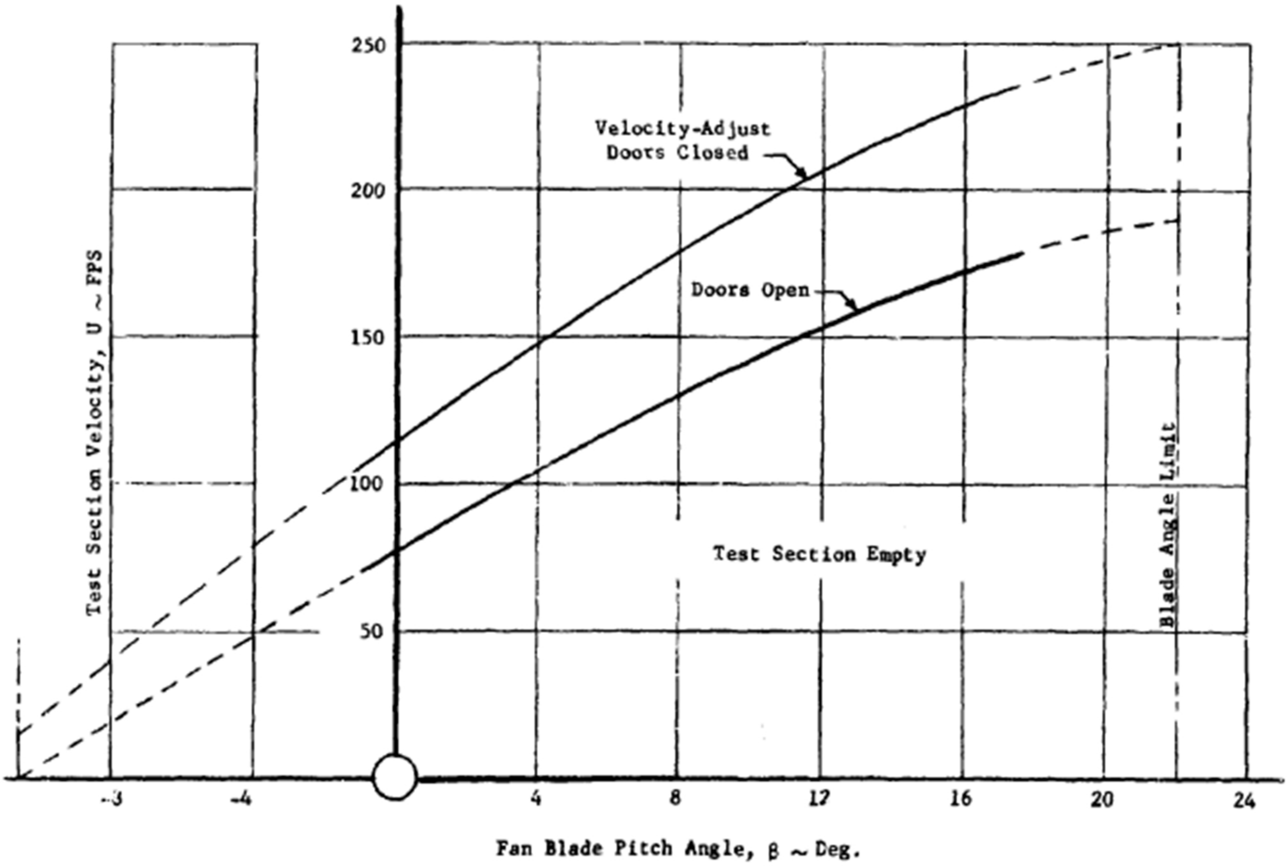

FIGURE 11. VELOCITY VARIATION WITH FAN BLADE PITCH ANGLE AND VELOCITY-ADJUST DOOR POSITION

Figure 2.2: Velocity Variation with Fan Blade Pitch Angle and Velocity-adjust Door Position

Source: Hoehne V.O., 1967

"Figure II shows the variation of air velocity with fan-blade pitch angle and with position of the velocity-adjust doors. These data depict flow conditions with the test section empty." (Hoehne V.O., 1967)

This graph shows that when the pitch angle increased, which mean the twist of blade increased, the test section air velocity also increased.

In this journal it also state that "The test conditions existing when the data in Figure 18 were recorded with three turbulence screens installed were achieved at two fan blade-pitch angle settings (8 and 10 degrees). This suggests pitch angle effects on turbulence within this range of variation are negligible. Further tests with spheres will be made, but wide ranges of pitch angle are impossible because the dependence of the critical Reynolds on sphere diameter limits the velocity range and, therefore, the blade pitch range."

"If the blower efficiency is not too important, these blades could be designed in the same way as corner vanes or cascades by choosing a leading edge angle of 4-5° and a zero trailing edge angle" (Mehta R.D *et al*,1979)

In this journal, it indicates that the choosing design of blade leading edge is 4-5° to avoid higher turbulence level and reduction of blower efficiency.

2.5 Importance of Reducing Turbulence Flow

"It is widely accepted that in a wind tunnel with a high turbulence level, premature transition from laminar to turbulent flow over the model surface may occur. This phenomenon is very critical when testing laminar flow models. The differences in the experimental values obtained in different wind tunnels having similar conditions and the same Reynolds number are due to the turbulence levels in those tunnels [5-18]." (Soltani M.R. *et al*,2010)

"A large contraction ratio helps reduce freestream turbulence and promotes cross-sectionally uniform flow in the test section." (Hoehne V. O,1967)

"One of the most important aspects of the flow quality in a wind-tunnel is the level of turbulence intensity. During the design of the wind-tunnel, a lot of work was devoted to ensure that the parts used for turbulence damping, such as screens, honeycomb and contraction would work well." (Lindgren B. *et al*, 2002)

These three journals show that the turbulence flow is not desirable and should be reduced in the test section as much as possible. This is because turbulence flow may affect the experimental values.

2.6 Importance of Enclosed Fan

"The motor delivers 15 kW of power. It is mounted axially behind the fan and it is enclosed in a steel plate cylinder to minimize the disturbance on the flow. Therefore, extra air for cooling the motor is provided from outside the wind-tunnel circuit through two cylindrical pipes." (Lindgren B. *et al*, 2002)

The statement explains that the enclosed fan is more desirable because it is automatically could prevent the disturbance of the flow from the outside.

2.7Axial Fan Blade Loads

"The use of axial fans can, however, create some flow quality problems, if they are subjected to very high loads, but even with more moderate loads they can create a low frequency pulsating variation of the streamwise flow component. In the present tunnel this is essentially, but not completely, avoided by a relatively low fan blade load." (Lindgren B. *et al*, 2002)

The above statement means that the high loads of fan blade could disturb flow quality in axial fans. Therefore, low fan blade load should be maintained.

"The load on the fan blades is also determined by the total pressure-loss of the wind-tunnel circuit. An increasing pressure-loss increases the blade load." (Lindgren B. *et al*, 2002)

Meanwhile this statement said that the total pressure-loss affect the blade load. The tip is to reduce the pressure-loss in order to reduce the blade load.

2.8 Pitot Tube as Pressure Measurement Instrument

"The measurement consisted in traversing a pitot tube across the guide-vanes at the center of their span and also to measure the static pressures upstream and downstream of corner 1." (Lindgren B. *et al*, 2002)

"A wide variety of velocity-measuring devices exist, and for the sake of brevity I will only touch on a few of the most popular. Pitot tubes are used to measure differences in pressure, usually with the aid of a manometer. In modern experimentation, it is common to utilize a device that combines a pitot tube with a static pressure measurement device so that both static pressure and stagnation pressure (total pressure) can be measured simultaneously. These devices are called pitot-static tubes, and can measure the different in total and static pressure, from which velocities can be calculated using the relation between dynamic pressure and fluid velocity." (Tatman N., 2008)

It is noted that these couple of research said that pitot tube can be used as pressure measurement instrument. It can be installed with manometer or pressure measurement device.

2.9 Reading the Pressure Parameter

"When using pitot tubes, care must be taken with regard to proper orientation of the tube, as a difference of only a few degrees from parallel to the flow lines could alter readings." (Tatman N., 2008)

The statement express that the orientation of the pitot tube is crucial due to a difference of degrees from parallel to the flow line will result in difference reading.

2.10 Causes of Mean Velocity Variation

"Variations in mean velocity can be caused by flow separations in the tunnel return circuit, flow separations in the contraction, poor corner vane design or incorrectly set vanes (resulting in the vanes over or under turning the flow), and poor design of the fan or straightening vanes (resulting in a rotation of the whole flow downstream of the fan)." (Lincoln P.E, 2000)

In this journal, variation of mean velocity may be cause by:

1. flow separations in the tunnel return circuit
2. flow separation in contraction
3. poor corner vane design
4. incorrectly set vanes
5. poor design of fan
6. poor design of straightening vanes

2.11 Methods for Improving the Flow

"Honeycombs and screens are known to improve the quality of the flow in the test section of a tunnel, both in terms of improved longitudinal and lateral mean-velocity distributions and reduced longitudinal and lateral turbulence intensities. Screens reduce longitudinal components of mean velocities and intensities more than lateral components, as for a contraction, whereas honeycombs reduce lateral components of mean velocities and intensities more than longitudinal components." (Lincoln P.E, 2000)

Lincoln said that the honeycombs and screen installation are the methods to improve the quality of the flow in test section by upgrading the longitudinal and literal mean-velocity distribution and also degrade the turbulence intensity.

2.12 Axial Flow Fans

“Axial Flow Fans are the devices that discharge the working fluid parallel to its axis of rotation. The working fluid is generally air and mostly they are operated in the incompressible range. Axial flow fans are generally used in mines, tunnels, underground transportation, all kinds of vehicles and industrial facilities for air conditioning and ventilation purposes in normal and emergency situations.”(Cevik F., 2010)

The statement elaborated about the axial fan operation and the use of it. Axial flow fan, which generally use for tunnel, could be installed at the wind tunnel to blow or suck air.

2.13 Vane Axial Fan

“A vane axial fan is very similar to a tube axial fan, except it has additional guide vanes to direct the flow into a more suitable path to the impellers or to remove the swirl component of the velocity to have additional gain of static pressure. The hub diameter is 50% to 80% percent of the impeller diameter. Vane axial fans can generate high volumetric flow rates and fairly high static pressure rise compared to the previous axial fan types.” (Cevik F., 2010)

The journal explains the vane axial fan specifications. The researcher also said that the axial fan is better in generating high volumetric flow rates and static pressure.

2.14 Maximum Flow Speed in Test Section

In the research by Lindgren B. and Johansson A.V, it is stated that, for the subsonic wind tunnel the maximum flow speed in the wind tunnel is 40 m/s. Flow speed in test section of subsonic wind tunnel should not be high because it is low speed wind tunnel.

"The main design criteria are listed in the table below,

1. Closed circuit wind-tunnel.
2. Good flow quality (mean flow variation, turbulence intensities & temperature variation).
3. Contraction ratio, CR, of 9.
4. Test section aspect ratio of 1.5 and the maximum test section length possible in the available space.
5. Maximum flow speed in the test section of at least 40 m/s.
6. Low noise level.
7. Low cost." (Lindgren B. *et al*, 2002)

2.15 Component Used for Turbulence Control

The following statement indicates that the function of screen. It could be used to minimize the turbulence in wind tunnel if it places at the entrance of the nozzle.

"There are several factors that screens are used in wind tunnels. One reason can be stated as to protect the fan. The other reason can be stated as to control flow separation in wide angle diffusers. It is also used for turbulence control for flow conditioning at the nozzle entrance." (Çevik F., 2010)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss the method, the process, and procedures of this research in detail. In addition, it is also discuss the materials, instruments and flow chart that will be use to complete this research.

3.2 Materials

The material use is steel plate for base and legs of fan, bolt and nut, welding filler, and plywood.

3.3 Instruments

In this research, the instruments use are three phase miniature circuit breaker (MCB), isolation switch box, power source socket, board, cable and cable lug, welding torch, three phase axial fan with motor, three phase AC inverter to control fan speed, pitot tube, digital pressure sensor, tube (manometer), digital manometer.